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THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Executive Summary

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Technology Transfer Study Center
George Mason University
Fairfax, Virginia

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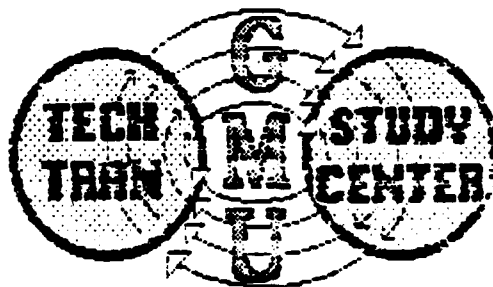
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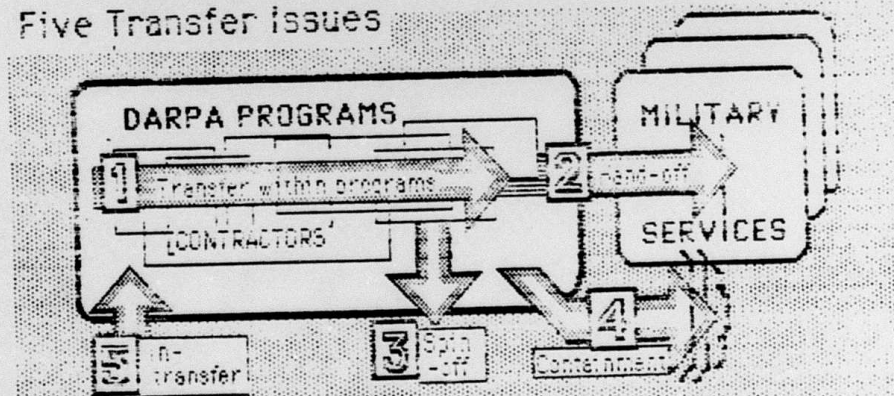
Executive Summary

The DARPA mission is to support leading edge R&D for national defense. The wide latitude in program initiation granted to this Agency over its 27-year lifetime has led to many advances contributing to national security. DARPA-sponsored R&D has also strengthened the overall national capacity in science and technology, contributing, thereby, to a strong national economy. Nonetheless, the means by which DARPA makes its contribution has never been fully understood. In 1984 George Mason University was awarded a contract to identify issues in technology transfer related to the DARPA mission. As part of that project a study was undertaken of current DARPA strategies, achievements, and problems in this arena. The study was based on interviews with some key officials in the Agency, an additional set of interviews with personnel in the three Armed Services and other branches of Department of Defense with experience related to DARPA programs, and documentation available on past Agency operations.

→ Five distinct transfer issues were uncovered, namely:

- [1] transfer within programs [*'intra-transfer'*];
- [2] transfer to military users [*'hand-off'*];
- [3] transfer to non-military users [*'spin-off'*];
- [4] undesired transfer or leakage [defined as the problem of *'knowledge containment'*]; and
- [5] transfer into DARPA from other sources [*'in-transfer'*].

Five Transfer issues



A synopsis of findings under each type of transfer follows.

I. Transfer within Programs

Uppermost in the minds of program managers is transfer of technology *within programs*. DARPA serves as a mechanism for creating, supporting, and *transferring* technologies. Its programs begin with conceptual and fundamental studies, then progress toward the development of new processes and techniques, and sometimes on to the conduct of demonstrations with manifest military applications. Each sequence involves a series of contractual arrangements with various institutions including universities, private firms, and one or another of the Armed Services. DARPA's small cadre of program managers oversees and attempts to facilitate the entire process of knowledge transformation and transfer from basic science to the demonstration of a direct military utility. Thus, *intra-transfer* describes what they do on a day-to-day basis.

DARPA has traditionally managed programs using seven strategies:

- * enlisting the best talent
- * encouraging social interaction
- * encouraging inter-institutional linkages
- * providing adequate and sustained fiscal support
- * concern for downstream applications
- * promoting creativity
- * supporting innovations which strengthen the R&D system

These elements combine in the hands of capable program managers to produce timely transitions from basic to applied research, from applied research to development, and from development to demonstration of use. As the new technology evolves, it transfers from the hands of researchers in universities to developers in private high technology firms. Different contractors appear to be able to pursue important leads independently yet to share critical findings with each other in timely fashion promoting synergy. All this often happens without the intrusion of a heavy DARPA hand.

The Agency has high confidence in this light-handed approach because it has seemed to work well so often. However, some shortcomings are noteworthy. Documentation of programs and projects is minimal, and there is no consistent policy for report distribution and review. Partly as a result of this and partly because duty tours are short, DARPA has an inadequate institutional memory.

With no systematic review of past performance, many questions about the management process go unanswered. What are the key stages of project development? What are the areas which are likely to cause the

most stress and discord? When should competitive bidding be required? How much forcing of interaction and collaboration is desirable to accelerate progress? How can we tell if important dissonant voices are given an adequate hearing? When are programs ready for transfer? DARPA has no mechanism for either self-evaluation or peer review, and therefore, no means of answering such questions. Partly as a result, it may be missing important opportunities to increase its effectiveness.

With the advent of the Strategic Computing Initiative, DARPA has entered a new era of systematic development planning. This program incorporates most of the seven features identified above as the Agency's modus operandi, but it also spells out a long-range plan with expected completion dates and interim performance requirements. This could become a model for DARPA program planning generally, provided that progress is documented and lessons are shared across the Agency. The critical task of management is to identify the points of *transition* where DARPA interventions are required, e.g. to expand a program, to redirect, to link universities and private firms, to bring in the military, to impose security classification, to transfer to another support agency or to terminate.

Implications. Although *intra-program transfer* works fairly well, it could probably work much better. The institutional memory could be strengthened by more consistent documentation of programs and agency-wide sharing of such documentation as exists. Such a process could force consideration of improvements in program management, including better identification and prediction of critical transitions.

2. Transfer to the Military

DARPA's primary mission is to add long-term value to the national security. Although most observers in the Pentagon and the Congress believe that the DARPA dollar has generated a manifold return, neither the amount of return nor the specific ways in which it happens have ever been documented. DARPA employs a number of stratagems to facilitate transfer of developed technologies to the services, but they have not always worked smoothly, and, in some cases, there have been serious disputes between DARPA and the Services on the value of DARPA-developed items. In examining individual cases, it is possible to point to some failed or very problematic transfer efforts as well as a number of outstanding successes. Even though the success stories give strong

evidence of DARPA's value, the frequency of failure, the persistence of conflict, and the consistency of certain criticisms of DARPA's approach suggest that there is considerable room for improvement and probably that the entire process should be overhauled.

We have identified many mechanisms that are used with some frequency, usually in combination, to strengthen the linkage between DARPA and the Services. Notable among these are:

- *the procurement process delegated by DARPA to the military services by long standing DoD policy;
- *participation in the DARPA contractor network and ARPANET by *some* researchers working on service-sponsored projects;
- *the involvement of some military units as "test beds" for DARPA demonstrations;
- *briefings for senior Service and DoD officials;
- *the recruitment of active duty military personnel to serve on DARPA staff.

Inadequacies were indicated in each of these areas. The Service-linked procurement process is *intended* to provide for serious Service involvement and a sense of co-ownership in a developing program. Sometimes it does this, but more frequently the Services are seen as merely pass-through agencies, and when they have sought greater involvement, this has sometimes become a source of tension in which Service acquisition authorities and their contracts personnel have felt their concerns were shunted.

Numerous military personnel and military R&D facilities participate in the DARPA network, and some are substantially involved at a technical level. However, DARPA does not like to load up important closed technical meetings with extras and does not view these as educational events or opportunities to link to the services. There is no uniform policy governing such participation.

Nearly one third of DARPA officials are active duty military officers and more than half have worked in some branch of the DoD prior to coming to DARPA. This fact may help linkage in some cases and not in others. Informants from the services have accused DARPA of sometimes hiring advocates of technologies which the services have already considered and passed over for substantial reasons. They see wastage of millions of precious R&D dollars in such ventures. DARPA's demonstrations of such technologies only set up the services as antagonists and make satisfactory hand-off virtually impossible.

DARPA Briefings for the Department of Defense and the Services are

well attended and highly appreciated but tend to be limited to senior officials who may not be the most appropriate audience for downstream procurement decisions. The influence of briefings may be further attenuated by the paucity of back-up documentation. Furthermore, there is no routine mechanism for follow up on expressed Service interests.

In a few instances, programs developed by DARPA have been transferred to other DoD units in their advanced stages [e.g. the transfer of the DEFENDER program to the Army Ballistic Missile Defense Agency in 1968, and the transfer of the Directed Energy program to the Strategic Defense Initiative Office in 1983] but such transfers clearly bring staff and budget shrinkage. There are considerable concerns for preservation of program integrity and technical quality in such transfers, but, beyond this, there is also understandable ambivalence about letting go when there is no provision for replenishment with new staff and unrestricted funds for new starts.

Implications Several types of activity might be considered by DARPA leadership to improve transfer to the military including a more comprehensive briefing process, a better mechanism to get service inputs to project selection, improved circulation of documents, more attention to recruitment of active duty military personnel, and the appointment of a special facilitator to oversee the hand-off process.

3. Domestic Spin-off

The third area, *spin-off* of technology from DARPA-supported efforts into private sector or non-military applications, has received minimal attention; no resources have gone either into the documentation or promotion of spin-offs. Nevertheless there is anecdotal evidence that DARPA has had considerable effect on the domestic economy through the spontaneous diffusion of various technologies it has spawned particularly in the computer field. Such spin-off has direct military value when the Armed Services later buy commercial products that embody that technology.

There is no guarantee that any advanced research program will ever pay off directly in militarily useful items, but it is desirable that any federally supported R&D program contribute as much as it can to the general welfare and especially the national economy even when projected military benefits fail to materialize. Additionally, there may always be unanticipated downstream application of military importance for technologies that DARPA supported at a much earlier date. It is often only

through private sector diffusion and development that certain types of applications become apparent. DARPA is in a better position to later capitalize on developments when it has earlier given them a good push into private development.

Implications. Although private sector *spin-off* is not generally viewed as within DARPA's purview, the Agency's historic inattention to this topic has been short-sighted, leading to lost opportunities which could ultimately have national security implications and resulting in the needless waste to the taxpayer. Lack of attention to this area also probably leads the Congress, the Executive Branch, and the general public to a gross undervaluing of DARPA's overall contribution to national strength.

4. Technical Knowledge Containment

The fourth area of high potential concern is the *containment* of technical knowledge deriving from DARPA programs and the limitation of its leakage to potential adversaries. DARPA's management philosophy generally encourages vigorous and many-channeled exploration of evolving technical possibilities among leading scientists and engineers. Therefore it does not seek security classification for much of its work. How much leakage is caused by this policy is not known in any precise way, and no attempt has been made to measure it.

The unclassified communications policy for basic work is justified on two principal grounds:

- *it encourages the best scientists to work for DARPA ;
- *high interaction brings most rapid technical advancement.

However, DARPA-sponsored communication is by no means a wide open process: DARPA's pervasive policy is to encourage small scale by-invitation-only technical conferencing at which Agency staff are present. Such an approach allows DARPA to have the earliest window on important new developments which might have serious security implications. Therefore containment actions including classification can be taken before any important cat is out of the bag. Furthermore, the very high order of free give-and-take communication among those present has the net effect of widening their technical lead over those not in the charmed circle. Thus DARPA's brand of contained 'openness' may actually enhance U.S. leadership in technology over all comers.

Strong arguments can be made in favor of the policy on these grounds, but equally strong arguments can be made that some kinds of openness

allow others to catch up, including potential adversaries. The assumption of relative advantage remains plausible but unexamined. The current arrangement is inherently leaky, making it all the more important for DARPA staff to track progress closely and to determine just the right moment for program transition to fully secured facilities.

Implications. The obvious importance of this topic has not been matched with concentrated efforts even to study the problem. All DARPA's contractors share a great concern for the security issue but few, if any, are able to propose viable countermeasures. There is a general fear that new restrictions on communication within the DARPA network would reduce creativity and productivity and might thus have a net negative effect on the nation's standing as a technology leader. Most obviously, however, the Agency could move on four fronts:

- *establish a more explicit set of policies for containment on a program-by-program basis, re-evaluating the policy as each program achieves intermediate objectives and makes significant transitions;
- *gather sample data on the extent of foreign contacts and other potential sources of leakage;
- *conduct experimental studies to get at answers to some fundamental dilemmas [as described more fully in Havelock (1985)];
- *convene special meetings to increase contractor sensitivity to containment issues.

5. Transfer into DARPA from Other Sources

A fifth type of transfer important to DARPA is "*in-transfer*"; "the acquisition of knowledge from other sources to enhance existing DARPA programs or to initiate new ones. DARPA is usually aggressive in exploiting new developments from its existing program portfolio but has no reliable process for acquiring new ideas from sources outside the DARPA contractor pool. There are no firmly established procedures for scanning, evaluating, or framing new programs. Furthermore, there may be an unfortunate tendency to perceive the existing DARPA network as the sole source for new ideas. Although DARPA has more budgetary latitude for new starts than most agencies, its very small staff is stretched thin keeping track of existing projects. Lack of established procedures, lack of staff time, and preoccupation with existing programs combine to make for a rather weak and haphazard in-transfer process.

Implications. DARPA needs an overall strategy for keeping abreast of new developments outside their own program areas. Better intelligence is needed on what is going on both in the U.S. and in foreign countries including the Soviet Bloc. Some system should be developed to provide a reliable early warning of scientific and technological developments, particularly in fields outside the current project portfolio of the agency. "No more surprises" was the original charge to DARPA in 1958. It remains the most valid rationale for the continuance of this agency in 1985; to meet that goal, it must do more than follow through on current program priorities. It must reach out aggressively for new technologies wherever they may be.

Recommendations

Our overriding recommendation is to greatly increase the priority of transfer issues at DARPA. The Undersecretary of Defense for D,R &E, the Director of DARPA, and the professional personnel of the Agency should significantly increase their concern for the full range of technology transfer issues covered in this report and seriously consider operational changes based on our findings. This means at the very least, reading the report and meeting to discuss its implications, item-by-item. Past inattention to this area has left the Agency with an unarticulated tech transfer "policy," guided neither by empirical knowledge or even serious thought. In this policy vacuum many good things have happened in the transfer of knowledge which have strengthened our national security immeasurably. These achievements are to be applauded, but they in no way indicate that the Agency fared better without a policy than it would have if transfer had been seriously attended to. Lack of deliberate and focused attention to optimizing transfer potential has probably cost us dearly. The loss to the nation from this inadvertence is incalculable and arguably larger than the gain we have experienced from all the R&D programs which we have undertaken.

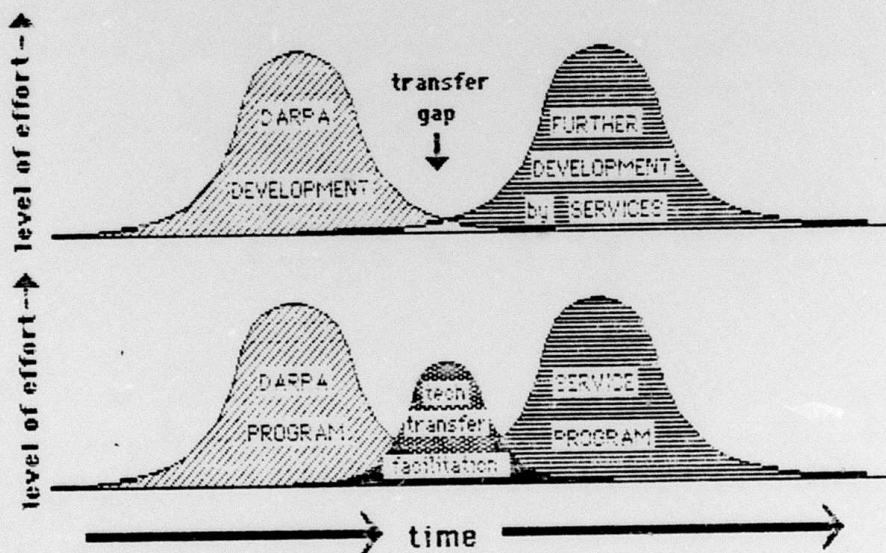
Beyond this general recommendation/admonition, we would like to offer five more specific recommendations, for early action to begin a more coherent and aggressive approach to transfer issues within the Agency. First, the Agency should immediately appoint a technology transfer *facilitator* to oversee the transition of developed technology to military use. Second, it should develop a state-of-the-art *on-line retrieval system* for tracking data on all projects and proposals. Third,

it should develop a new system of program tracking to identify critical stages and outcomes, which we call *transition analysis*. Fourth, it should convene a *panel on access to unclassified technical knowledge*. Finally, it should establish an annual *forum for the review of newly emerging technologies*. A brief summary of each recommendation follows. *is given.*

1. The Technology Transfer Facilitator

DARPA should designate a new full-time technology transfer facilitator to focus attention on the transfer of DARPA-developed technology to the military services. The military technology hand-off is DARPA's top priority, and our analysis indicates that it has been poorly managed since the earliest days of the Agency. One person with high energy, seniority, and wide experience in military R&D management should be especially recruited to serve in this new role and should be relieved of all other duties. The figure below illustrates the problem and the proposed solution.

The Facilitator Role in Transfer to the Services



The transfer facilitator would have four areas of responsibility: [1] to make sure that DARPA programs which are reaching maturity transfer smoothly into use or further development by appropriate Services; [2] to

track the changing needs and requirements of the Services and to make sure that relevant DARPA staff and programs are cognizant of those needs; [3] to plan and supervise the DARPA briefing process for the Services so that [a] appropriate levels are reached, [b] connections are made among the most knowledgeable technical personnel, and [c] all briefings are supported by documentation calibrated to the technical level and "need-to-know" characteristics of the audience; and [4] to monitor and, when necessary, serve as trouble shooter in relations between DARPA staff and Service units responsible for procurement and monitoring of DARPA-sponsored projects.

2. A State-of-the-art On-line Retrieval System

DARPA should develop its own on-line project data base for contractor reports and proposals, employing state-of-the-art bibliographic systems to allow *full text* searching and graphics displays. Expectations that such a system would be of great value not only to DARPA but to the military services in general are enhanced by recent developments in compact laser disc storage capabilities as well as greatly increased sophistication of storage-access software. Such a system would allow much more accurate assessments of the current status of projects and whole programs with a view to identifying critical transition points where DARPA interventions are needed, e.g. to provide more funding, to impose security restrictions, to involve military services or other types of contractors to a greater extent, to convene special meetings, etc. A very sophisticated system is needed to compensate for the shortage of DARPA personnel available to supervise programs and the inability of the agency to send representatives to every relevant meeting or to involve itself directly in every key decision made as programs develop. It would also be an important and perhaps essential tool to aid the proposed technology transfer facilitator in identifying transfer readiness and potential trouble spots across a diverse set of programs.

3. Transitional Analysis Reporting

As a third recommendation we feel that the Agency should prepare for its own use program transition analysis reports, five-year retrospective reports on a specified sub-set of its major programs to define and identify stages of development together with a listing of

outcomes or impacts expected and achieved at each stage. The purpose of this report is to force an identification and agency-wide consensus on critical transition points where special consideration should be given to [a] dissemination of findings to a wider or different type of audience, [b] changes in the approach to procurement, [c] stronger links to one or another military service or other DoD unit, and [d] possible controls on the flow of information.

The first retrospective five year reports would be a prelude to on-going five year reports and to similar reports for all DARPA program areas. The result would be a much stronger institutional memory and greater agency-wide consensus and focus on critical transfer issues. The capability to identify and to track development stages of a program in an accurate and timely fashion are the key to good management at DARPA. As these analyses become more sophisticated and as consensus is reached on key variables and their identification, report data can start to feed into the on-line data retrieval system discussed above as our second recommendation. To reduce load on DARPA managers it would probably be desirable to engage a contractor to perform the prototype reports and devise a workable set of procedures.

4. Panel on Access to Unclassified Technical Knowledge

The DARPA director should initiate action to establish a panel on access to unclassified technical knowledge. This panel would concern itself *exclusively* with DARPA-sponsored projects and should probably be made up primarily of senior investigators who have been associated with DARPA programs over an extended period. The charge to the panel would include three tasks: [1] to prepare a preliminary DARPA policy statement on the dissemination and/or containment of unclassified knowledge emanating from DARPA projects; [2] to determine what kinds of data should be collected to begin building an empirical base for future containment decisions and policies; and [3] to develop a process for periodic review of the containment issue including possibly the establishment of a standing review committee.

5. A Budding Technologies Forum

DARPA should institute an annual mini-conference to identify and evaluate new technologies. The purpose would be to seek out areas whose

relevance to military or other applications is just beginning to be perceived. These would also be areas that are not currently represented or adequately represented in the DARPA portfolio. A review panel should be composed of leading science administrators, policy makers, and scientists who have a proven track record in identifying important developments at early stages. Ideas for presentations should be solicited from diverse sources inside and outside the government and should be screened and reviewed on a competitive basis to limit presentations to the forum of only concepts with [a] significant downstream application potential, [b] originality, [c] soundness of logic, and [d] soundness of empirical basis. Concepts which are presented should be given full consideration including a written response which specifies follow-on recommendations. The forum would fill a significant gap in DARPA's current *modus operandi*, namely the in-transfer of new program ideas on a regular basis, taking full advantage of the *national* capacity to generate ideas worthy of DARPA support.